

Thermal Modelling of Alkaline Water Electrolyzer for Green Hydrogen Production

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Extended Abstract

Hydrogen energy is a suitable sustainable alternative to fossil fuels compared to intermittent renewable energy resources. Alkaline water electrolyzers (AWE) produce green hydrogen with the help of the electrolysis process. This process is environment-friendly and free of harmful emissions, unlike hydrocarbon methods for the production of hydrogen. AWE is a mature, robust and cost-effective technology. So, AWE is the finest option for green hydrogen production.

Experimental studies alone do not give parameter distribution throughout the domain of AWE. However, computational modelling of the AWE cell, especially thermal modelling, has this capability, enabling optimization of the design and improving the hydrogen production rate. Temperature rise in the AWE cell reduces the overpotential requirement for the cell and increases thermal efficiency. The high increment of temperature inside the cell causes material degradation of the electrode and the separator, resulting in reduced cell life and decreased hydrogen purity. To improve the life span of the AWE cell, thermal modelling is required for proper thermal balance and to optimize hydrogen production.

Most of the studies of thermal modelling considered a time-dependent model (0D) [3]. Very few studies [1,2] give 1D temperature distribution and parameter variation concerning temperature. But these 1D studies only consider the variation of parameters along a flow direction. Lateral variation is neglected here, which does not provide temperature as well as hydrogen production distribution over the entire electrode surface. So, there is a very strong need to introduce a 2D model to study the actual local characteristics and modify the electrode as well as the cell design accordingly.

The present study proposes a semi-empirical, four-parameter, 2D model of the AWE cell to predict cell voltage. The current study aims to investigate hot spots on a cell's lateral surface (x-y plane), which will help to optimize cooling strategies and electrode geometries. To achieve this, the proposed 2D model is coupled with 2D mass conservation, species conservation, momentum and energy equations, which are solved using Computational Fluid Dynamics (CFD) techniques. Computational methodology includes fixing the cell voltage and determining the current density value using the cell voltage equation. The momentum equation determines the x and y direction flow velocities. Further current density and flow velocities solve mass and species conservation equations to assess electrolyte and gases (H₂ & O₂) molar flow rates. The last step of computation is to determine the temperature distribution by using the energy conservation equation. Overall, this 2D model provides detailed output, including temperature distribution, hydrogen production, water consumption, current density distribution and weight concentration variation in the flow direction (x) and laterally (y) along the electrode surface. Lateral variation in parameters enables the identification of local hotspots of heat accumulation, which in turn causes localized temperature rise within the cell. Local temperature rise creates a temperature gradient across the cell, ultimately resulting in a decrease in hydrogen production. The present study detects critical areas of heat accumulation, unlike the 1D model. Also, it shows that a lower temperature gradient gives higher thermal efficiency and optimum hydrogen production.

References

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